PATENT ABSTRACTS OF JAPAN

(11)Publication number : 11-051965

(43)Date of publication of application : 26.02.1999

(51)Int.Cl. G01P 15/125

(21)Application number : 10-167489

(22)Date of filing : 15.06.1998

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(30)Priority

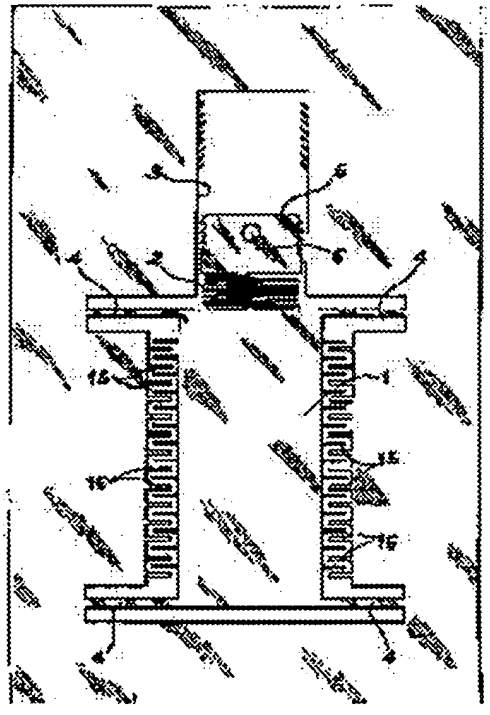
Priority number : 97 9707502 Priority date : 17.06.1997 Priority country : FR

(54) SMALL-SIZED ACCELEROMETER OF TYPE USING GRAVITATIONAL EFFECT COMPENSATING SPRING AND MANUFACTURE THEREOF

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a small-sized and high-sensitivity accelerometer capable of being manufactured at low cost.

SOLUTION: A small-sized accelerometer is provided with a supporting body, a weight 1, beams 4 that are positioned between the supporting body and the weight 1 and capable of being bent by the influence of the force due to the acceleration to be measured, a detecting means capable of determining the acceleration on the basis of the force induced inside the weight 1, and a spring 2 for compensating the force brought to the weight 1 by means of gravitation; and the supporting body, the weight 1, the beams 4, and the spring 2 are members manufactured inside the same base plate 10, and the accelerometer is also provided with a spring head 5 for arranging the spring 2 by means of a mechanical tension and with a fitting means for the head 5, thereby compensating the force brought to the weight 1 by means of gravitation.



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[Date of request for examination]

[Date of sending the examiner's decision of rejection]

[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]

[Date of final disposal for application]

[Patent number]

[Date of registration]

[Number of appeal against examiner's decision of rejection]

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CLAIMS

[Claim(s)]
[Claim 1] It is the miniaturized accelerometer. - measurement with - base material The weight put to the force in which induction was carried out by the acceleration which should be carried out, - The mechanical connection means at which can be located between said base materials and said weights, and it can turn under the effect of said force, - While compensating a detection means by which said acceleration can be determined based on the force by which induction was carried out in said weight, and the force brought to said weight with - gravity It comes to provide the elastic compensation means for connecting said weight and said base material. Said base material, said weight, said mechanical connection means, and said elastic compensation means it is the member manufactured in the same substrate, the adjustment means for arranging said elastic compensation means with mechanical tension is established, and it is characterized by this compensating said force brought to said weight with gravity -- small -- an accelerometer.
[Claim 2] Said elastic compensation means is equipped with at least one spring. The end of this spring It unites with one member of said base material or said weight. The other end The accelerometer according to claim 1 which displacement of is enabled by said adjustment means, and is characterized by being attached in the member of another side of said base material or said weight, and this arranging said spring where said mechanical tension is impressed.
[Claim 3] Said adjustment means is an accelerometer according to claim 2 characterized by the ability to make an one direction carry out the variation rate of said movable end of said spring.
[Claim 4] It is the accelerometer according to claim 3 which said adjustment means is equipped with a flexible blade and the maintenance stop section, and is characterized by the ability to prepare these flexible blades and the maintenance stop section possible [engagement] in the member of the direction where said movable end of said base materials and said weights is connected [near / said / the movable end of said spring].
[Claim 5] The accelerometer according to claim 4 with which spacing of said flexible blade is characterized by differing from spacing of said maintenance stop section.
[Claim 6] The accelerometer according to claim 1 with which said detection means is characterized by being a capacity detection means.
[Claim 7] It is the accelerometer according to claim 6 which said capacity detection means is equipped with two or more gear teeth fixed to said base material, and two or more gear teeth fixed to said weight so that the 2nd electrode might be formed so that the 1st electrode may be formed, and is characterized by arranging them as these gear teeth form a split-fingered fastball transducer.
[Claim 8] The accelerometer according to claim 1 with which it is characterized by said substrate consisting of a solid-state quartz or a silicon block.
[Claim 9] The accelerometer according to claim 1 characterized by said substrate being the product made from silicon considered as the insulator type.
[Claim 10] the inside of the substrate made from a predetermined ingredient -- at least one -- small -- by being an approach for manufacturing an accelerometer and etching said substrate according to a

substrate thickness - The mechanical connection means at which it can turn under the effect of the force in which was located between a base material, - weight, and the - aforementioned base material and said weight, and induction was carried out by the acceleration which should be measured, - While uniting with one member of said base material or said weight, an end At least one member to which the other end makes the spring connected with the head with an attachment means, - The attachment means formed in the member of another side of said base material or said weight corresponding to said attachment means of said spring head, The approach characterized by compensating the force brought to said weight with gravity by forming, and attaching the b aforementioned spring head to the member of another side of said base material or said weight where mechanical tension is received.

[Claim 11] In the substrate with which silicon has been arranged on an insulator, i.e., the substrate which a silicon wafer is first covered with a silicon oxide layer, and the degree comes to cover with a silicon layer at least one -- small -- the approach for manufacturing an accelerometer -- it is -- a -- until it reaches said silicon oxide layer By etching said silicon layer, - base material and - weight, - While -1 edge is united with the mechanical connection means at which it can turn under the effect of the force in which was located between said base materials and said weights, and induction was carried out by the acceleration which should be measured by one member of said base material or said weight At least one member to which the other end makes the spring connected with the head with an attachment means, - The attachment means formed in the member of another side of said base material or said weight corresponding to said attachment means of said spring head, By forming, removing said silicon oxide layer located under said members other than the b aforementioned base material, and attaching the c aforementioned spring head to the member of another side of said base material or said weight, where mechanical tension is received The approach characterized by compensating the force brought to said weight with gravity.

[Claim 12] the approach according to claim 10 or 11 characterized by forming the gear tooth arranged as comes out with two or more gear teeth fixed to said base material so that the 1st electrode might be formed further, and two or more gear teeth fixed to said weight so that the 2nd electrode might be formed, exists by said etching and formed the split-fingered fastball transducer.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the accelerometer with which the type which used the spring for compensating the gravity effectiveness was miniaturized. This invention relates to the manufacture approach of such an accelerometer again.
[0002] This invention can compensate the effectiveness of the gravity which an object receives, therefore can raise the sensibility to acceleration change. this invention -- further -- a detail -- microelectronics (and micro machine NINGU) -- it is applied to the machine device of the small dimension manufactured by law. The main fields of application of an accelerometer are a motion of the medium which receives gravity, and research (for example, seismology) of behavior.
[0003]
[Description of the Prior Art] An accelerometer or an acceleration sensor is equipped with the weight member usually supported by one or more flexible members, and is constituted. When this weight receives acceleration change, weight displaces and a flexible member deforms. A system will return to an initial valve position, shortly after the force based on acceleration is canceled. In being in a non-operating state, a horizontal acceleration sensor receives neither the force nor any stress. The accelerometer by which orientation was conversely carried out substantially to this in the direction of a vertical receives the minute eternal force F based on gravity. This force F is expressed with F=Mg, when M is made into the mass of weight and it makes g a gravitational constant.
[0004] This eternal force is applied to a measurement signal. Therefore, enhancement of the dynamic characteristics of a sensor is needed [which it says is 10 - 6 or less g] to measure the small direction acceleration of a vertical very much. Therefore, in such a case, it is important to compensate the force based on gravity according to the fixed force of turning to an opposite direction.
[0005] The approach used in order to compensate the effect by gravity can be classified into two categories. That is, it can classify into what uses a power source, and the thing which uses the return force of a spring.
[0006] In the approach of using a power source or an energy source, the electrostatic force or electromagnetic force for maintaining weight in the suspension condition is used. The system with which gravity is compensated according to electrostatic force or electromagnetic force is complicated and expensive. Such a system consumes power and uses a servo loop. When it comes to a noise source, in the case of electrostatic force, control of stability is difficult for such both servo loops especially. Only electrostatic [these] or an electromagnetic compensatory system is being used for the accelerometer produced using the microelectronics method in spite of the fault of electrostatic or an electromagnetic compensatory system the place to current. This is because the easy method of manufacturing the spring lengthened or pulled by the mass-production-method-approach until now was not proposed.
[0007] The gravity compensatory system which used the return force of a spring is generally used in the facility manufactured as the base in the conventional mechanical approach, i.e., the method of carrying

out machining and assembling the posterior part material. however, the recently and French country patent application specification 2nd -- in 735 580 No., while weight was maintained by equilibrium with the spring with which prestress was given, the accelerometer which can manufacture weight by the approach of using mechanics micro mechanics microelectronics as the base was proposed. The proposed compensation approach is using theoretically as the base the spring of the gestalt of the blade or leaf manufactured by giving prestress to the front face of the member (for example, beam) which supports weight.

[0008] The hybrid system which used the both sides of electrostatic force or electromagnetic force, the return force by the spring, and ** for the last exists. such a hybrid system -- Mr. S.J.Chen and K -- J.Phys.E. by Mr. Chen: "The Effects of Spring and Magnetic Distortions on ElectromagneticGeophones" in Sci.Instrum., 21, 1998, and pp 943-947 ** -- it is indicated by the reference to entitle.

[0009] The gravity compensation approach by the spring has the advantage that there is no bag ground noise generated by the automatic control system as compared with the approach which used the power source. Moreover, the compensation by the spring is simple, stable, is cheap, and can bring about a still more reliable approach.

[0010] The acceleration sensor which has a substantial vertical directional axis where the effect of gravity to weight is compensated with the spring is manufactured by now assembling various machine part. In this configuration technique, such a device does not have the very big quality factor Q. This structure parameter is connected with the BURAUN noise consistency S of a device by the following formulas. In this formula, it is shown that S is in inverse proportion to Q and M.

[Equation 1]

$$s = \sqrt{\frac{4k_b T \omega_r}{MQ\left\{\left(\omega^2 - \omega_r^2\right)^2 + \frac{\omega^2 \omega_r^2}{Q^2}\right\}}}$$

ここで $$Q = \frac{2\pi\omega_r}{M\lambda}$$

in this case, lambda : A damping coefficient and omega : A frequency, omegar:resonance frequency, kb:Boltzmann's constant, and T : temperature -- it comes out.

[0011] In order to maintain so that it may not become the failure of measurement of a BURAUN noise, the existing device has the big mass M. Nevertheless, this means restricts the miniaturization of an assembly. Therefore, the minimum high performance (as [measure / under the situation of 1G / several nano G]) means serves as weight of several kg, and is 3 dozens of cm. It becomes the volume.

[0012] It is necessary to make mass M small, therefore to enlarge a quality factor for the miniaturization of a high performance device. This is obtained by forming the whole (weight and spring) sensor from the ingredient which has a big quality factor like single crystal silicon. However, a technical trouble occurs on the occasion of manufacture of the compact device which has the spring united with weight. That is, it is difficult to link by mechanical means, such as a screw and adhesives, without generating a field where internal friction causes a large attenuation phenomenon harmful to a quality factor for small machine parts, such as a spring and weight. Moreover, it is required for the sensibility of a sensor to maintain the affecting big flexibility of a spring as shown in the following formulas.

[Equation 2]

$$s = \frac{1}{k} \quad \text{および} \quad S = \frac{M}{K + k}$$

in this case, the rigidity of the device in the case of having the flexibility of s:spring, the rigidity of

k:spring, S:sensibility, and no K:spring compensation -- it comes out.
[0013] The purpose of this invention is proposing the accelerometer with which the type with which gravity's is compensated with a spring was miniaturized. This accelerometer can be manufactured by the microelectronics-manufacture technique of bringing about the following advantages. That is, it is low cost, and it is small and the advantage that the mechanical quality of an ingredient is good can be brought about. This result is obtained by manufacturing various members of an accelerometer in the single substrate which can be used as a compound substrate.
[0014]
[Means for Solving the Problem] The purpose of this invention is the miniaturized accelerometer. Therefore, - base material, - The mechanical connection means at which can be located between the weight put to the force in which induction was carried out by the acceleration which should be measured, and the - aforementioned base material and said weight, and it can turn under the effect of said force, - While compensating a detection means by which said acceleration can be determined based on the force by which induction was carried out in said weight, and the force brought to said weight with - gravity It comes to provide the elastic compensation means for connecting said weight and said base material. Said base material, said weight, said mechanical connection means, and said elastic compensation means it is the member manufactured in the same substrate, the adjustment means for arranging said elastic compensation means with mechanical tension is established, and it is characterized by this compensating said force brought to said weight with gravity -- small -- it is an accelerometer.
[0015] Advantageously, an elastic compensation means is equipped with at least one spring with both ends, and it unites with one member of a base material or weight, and thereby, where mechanical tension is impressed, it arranges [it is attached in the member of another side of a base material or weight, the end of this spring being used as displacement with an adjustment means being possible for the other end, and] a spring.
[0016] An adjustment means can make the movable end of a spring the means which an one direction can be made to carry out a variation rate. In this case, an adjustment means can be equipped with a flexible leaf or a blade, and a maintenance contact object or the maintenance stop section, and these flexible blades and the maintenance stop section are prepared possible [engagement] [near the movable end of a spring] in the member of the direction where the movable end of a base material and the weights is connected.
[0017] A detection means can be made into a capacity detection means. In this case, a capacity detection means can be equipped with two or more gear teeth fixed to the base material, and two or more gear teeth fixed to weight so that the 2nd electrode might be formed so that the 1st electrode may be formed, and as these gear teeth form a split-fingered fastball transducer (the shape of or a ctenidium), they are arranged.
[0018] A substrate can be made into the thing of the type (SOI type) with which it could constitute from a solid-state quartz or a silicon block, and silicon has been arranged on an insulator.
[0019] other purposes of this invention -- the inside of the substrate made from a predetermined ingredient -- at least one -- small -- by being an approach for manufacturing an accelerometer and etching said substrate according to a substrate thickness - The mechanical connection means at which it can turn under the effect of the force in which was located between a base material, - weight, and the - aforementioned base material and said weight, and induction was carried out by the acceleration which should be measured, - While uniting with one member of said base material or said weight, an end At least one member to which the other end makes the spring connected with the head with an attachment means (the 1st), - The attachment means formed in the member of another side of said base material or said weight corresponding to the aforementioned attachment means (the 1st) of said spring head (the 2nd), It is the approach characterized by compensating the force brought to said weight with gravity by forming, and attaching the b aforementioned spring head to the member of another side of said base material or said weight, where mechanical tension is received.
[0020] The substrate with which, as for the purpose of further others of this invention, silicon has been arranged on an insulator, Namely, in the substrate which a silicon wafer is first covered with a silicon

oxide layer, and the degree comes to cover with a silicon layer at least one -- small -- the approach for manufacturing an accelerometer -- it is -- a -- until it reaches said silicon oxide layer By etching said silicon layer, - base material and - weight, - While -1 edge is united with the mechanical connection means at which it can turn under the effect of the force in which was located between said base materials and said weights, and induction was carried out by the acceleration which should be measured by one member of said base material or said weight At least one member to which the other end makes the spring connected with the head with an attachment means (the 1st), - The attachment means formed in the member of another side of said base material or said weight corresponding to the aforementioned attachment means (the 1st) of said spring head (the 2nd), By forming, removing said silicon oxide layer located under said members other than the b aforementioned base material, and attaching the c aforementioned spring head to the member of another side of said base material or said weight, where mechanical tension is received It is the approach characterized by compensating the force brought to said weight with gravity.

[0021] by etching, it comes out with two or more gear teeth fixed to said base material so that the 1st electrode might be formed further, and two or more gear teeth fixed to said weight so that the 2nd electrode might be formed, it is, and the gear tooth arranged as formed the split-fingered fastball transducer can be formed.

[0022]

[Embodiment of the Invention] Hereafter, the nonrestrictive operation gestalt of this invention is explained to a detail with reference to an accompanying drawing.

[0023] drawing 1 is based on this invention -- small -- it is the top view showing the substrate etched in order to obtain an accelerometer. Drawing 2 is the perspective view showing the machine part of the accelerometer by this invention, and the effect by gravity is compensated. Drawing 3 is drawing showing a part of drawing 2 in a detail.

[0024] For example, it is an electrostatic-capacity detection type thing, and is a small dimension (for example, even if it is max 2cm 2). The manufacture of the machine part of the accelerometer by this invention which used the microelectronics-technique in which the accelerometer carried out could be obtained is explained. the French country patent application specification 2nd which indicated "the manufacture approach of the accelerometer which used the SOI (Siliconon Insulator) technique" about the further detail of the microelectronics-technique -- 700 065 No. can be referred to.

[0025] Manufacture can be performed in mass production method. For example, five devices can be manufactured on a 4 inches (10.16cm) single crystal silicon substrate.

[0026] The compensation approach proposed to the accelerometer as shown in drawing 1 - drawing 3 includes manufacture of the spring made from silicon united with weight. The spring is beforehand pulled until the force which a spring causes by carrying out the variation rate of the free end (namely, the edge holding weight edge of the opposite side) of a spring balances the mass of the weight which is supporting the spring. After that, the movable end of a spring is locked by the adjusted location so that it may mention later.

[0027] By using the substrate made from a single crystal ingredient (silicon, quartz), a big quality factor can be obtained to small weight M. By using micro technology, a miniaturization is possible and it can mass-produce. That is, low cost production is possible.

[0028] Drawing 1 - drawing 3 show manufacture of the machine part of an accelerometer from a SOI type substrate. the silicon oxide layer 12 and the single-crystal-silicon layer 13 with which this substrate 10 covers a silicon wafer 11 and this silicon wafer 11 in order -- since -- it is constituted (refer to drawing 2). Such a substrate can be obtained by other well-known approaches. The thickness of the silicon layer 13 can be changed over 400nm - 1mm according to a request or the SOI substrate manufacture approach. an accelerometer single for the purpose of simplification -- only structure is illustrated.

[0029] A resin mask is formed in the free surface of a layer 13 by photolithography. Then, a layer 13 is etched by the anisotropy plasma-etching method. Such an etching method is indicated by the reference it is ["A Survey on the Reactive Ion Etching of Siliconin Microtechnology" in J.Micromech.Microeng. / /

else / H.Jansen Mr. /, 6, 1996, and pp 14-28] entitled. Etching is performed to the bottom of the silica layer 12. Then, in order to separate a part for moving part from the remainder of a substrate 10, the silica part which was located in the hollow formed in the layer 13, and was located directly under [for moving part] is dissolved.

[0030] By etching, the hollow 3 for weight 1, the member 2 which will function as a spring when stretched, and a spring 2 can be formed. Weight 1 is connected with the remainder of a substrate through four beams 4 at which it can turn under the effect of the acceleration which should be measured. Etching has left the spring 2 connected with weight 1. With the edge connected with the weight of the springs 2, the part 5 called a spring head is formed in the edge of the opposite side as the extension. The hole 6 is formed in the spring head 5 in order to make the handling of the spring head 5 easy.

[0031] The silica is removed in the continuation front face constituted by a hollow 3, weight 1, a beam 4, the part of the weight circumference, and the part of the beam circumference. In this case, the base material is constituted by the part to which the layer 13 was left behind, the insulating layer 12, and the wafer 11.

[0032] Moreover, etching has left the flexible leaf or flexible blade 31 connected with the wall of a hollow 3 (refer to drawing 3). To the shaft of a spring 2, these flexible blades 31 have countered with the maintenance stop section 51 formed on the wall of the spring head 5 while they are parallel. Therefore, the flexible blade 31 and the maintenance stop section 51 have the depth corresponding to the thickness of the silicon layer 13.

[0033] For example, thickness of the silicon layer 13 can be set to 200 micrometers, the die length of the flexible blade 31 can be set to 250 micrometers, and thickness of the flexible blade 31 can be set to 10 micrometers. The inclination of the flexible blade 31 can be made into 45 degrees. The maintenance stop section 51 can be made into the thing of a triangle cross-section configuration. The overlap die length of the flexible blade 31 and the maintenance stop section 51 can be set to 14 micrometers.

[0034] The accelerometer of illustration is a capacity detection type thing. Two or more gear teeth arranged by etching in both the sides of weight for this purpose as constituted the split-fingered fastball transducer while being able to constitute the electrode are formed. To the beam 4 of the weights 1, on a perpendicular wall, two or more support gear teeth 15 are formed, and two or more support gear teeth 16 are formed on the opposite wall of the base materials. A series of capacitors are obtained by performing metallic-coating processing to these gear teeth. Each capacitor which constitutes a series of capacitors is specified by the space between a gear tooth 15 and the opposite gear tooth 16.

[0035] In order to compensate gravity, the spring head 5 uses the acute tool introduced in the hole 6 of a head, and a variation rate is carried out to weight in an opposite direction. Thereby, a spring is pulled. The flexible blade 31 collaborates with the maintenance stop section, and brings about the function of the both sides of the adjustment function of the location of the spring head 5, and a maintenance function. Adjustment can be performed by changing an accelerometer into a vertical condition. A spring is pulled until the force brought about with a spring compensates the mass of weight. The check of the variation rate of weight can be performed by measuring each capacitance value to each split-fingered fastball transducer system (if two capacitance values are the same, weight is in equilibrium).

[0036] By carrying out inclination arrangement again, the prestress which could block the variation rate of a spring head clearly in the one direction, therefore was impressed to the spring is maintainable by carrying out symmetry arrangement of the flexible blade 31. When a flexible blade and the maintenance stop section displace relatively, a spring head can be correctly arranged to a base material.

[0037] The relative configuration of the maintenance stop section 51 and the flexible blade 31 can be performed in the way of vernier calipers. By preparing different spacing to the stop section and a blade, the location of a spring head can be adjusted as it is also at the precision which improved.

[0038] As the 1st example of SOI structure, the thickness of a spring It can be referred to as 200 micrometers (thickness of a silicon layer). The width of face of a spring It can be referred to as 1850 micrometers. (Corresponding to the width of face of a hollow 3) The thickness of a spring blade It can be referred to as 10 micrometers, and the number of the blades arranged in the shape of zigzag can be made into 200 pieces, and mass of the extension die length / weight of most springs can be set to

25mm / 0.2g, respectively.
[0039] As the 2nd example of SOI structure, the thickness of a spring It can be referred to as 200 micrometers. Moreover, the width of face of a spring It can be referred to as 5000 micrometers. The thickness of a spring blade It can be referred to as 30 micrometers, and the number of the blades arranged in the shape of zigzag can be made into ten pieces, and mass of the extension die length / weight of most springs can be set to 0.9mm / 0.07g, respectively.
[0040] In the case of a solid-state substrate (single crystal silicon or quartz block), etching is performed by penetrating covering the whole substrate thickness.
[0041] Thus, it is a dimension small on the whole, and the seismometer which can be introduced in a digging well can be manufactured.

[Translation done.]

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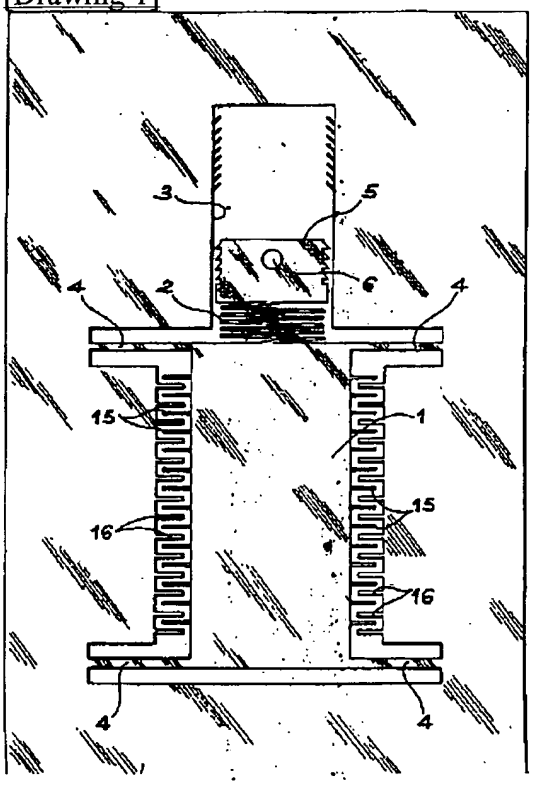
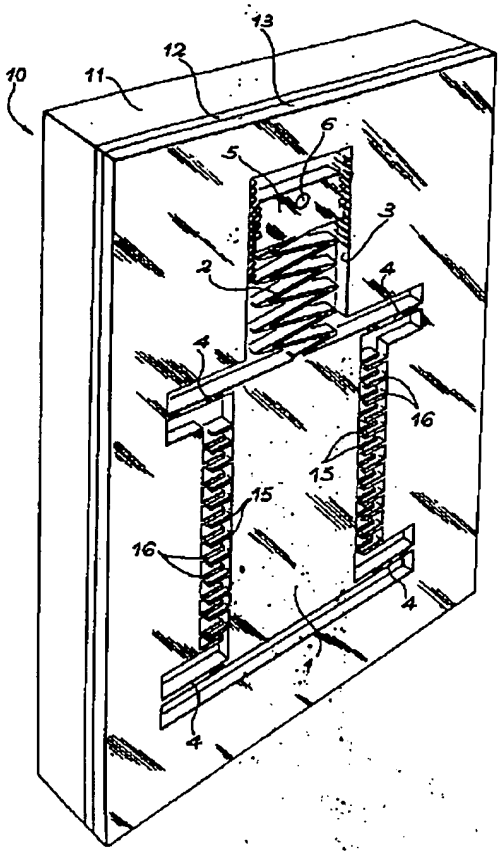
DRAWINGS

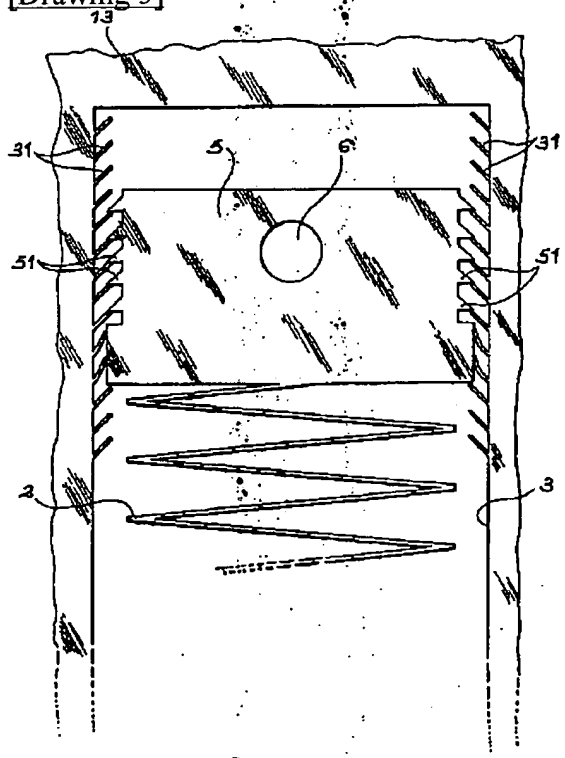
[Drawing 1]



[Drawing 2]



[Drawing 3]



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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] it is based on this invention -- small -- it is the top view showing the substrate etched in order to obtain an accelerometer.
[Drawing 2] It is the perspective view showing the machine part of the accelerometer by this invention.
[Drawing 3] It is drawing showing a part of drawing 2 in a detail.
[Description of Notations]
1 Weight
2 Spring
3 Hollow
4 Beam (Mechanical Connection Means)
5 Spring Head
10 Substrate
11 Silicon Wafer
12 Silicon Oxide Layer
13 Single-Crystal-Silicon Layer
15 Gear Tooth
16 Gear Tooth
31 Flexible Blade
51 Maintenance Stop Section

[Translation done.]